REPORT ON GRASS WATERWAYS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

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REPORT ON GRASS WATERWAYS

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FOREWORD

At the Operations Planning Meeting during the week of May 8, 1956, at Potato City, Pennsylvania, a committee was appointed to study and prepare a report on Grass Waterways in the Northeast. This report deals primarily with problems in natural and constructed waterways.

ACKNOWLEDGMENT

The Committee wishes to express its appreciation for the assistance given by John Lamb, Research Liaison Representative, Ithaca, N. Y.; W. W. Steiner, Plant Materials Specialist, SCS, Upper Darby, Pa.; Harold Hobbs, Hydrologist, ARS, College Park, Md.; D. D. Smith, Agricultural Engineer, ARS, Beltsville, Md.; W. O. Ree, Hydraulic Engineer, ARS, Stillwater, Oklahoma; and Lester Fox, Information Specialist, SCS, Upper Darby, Pa., in supplying information used in the preparation of this report.

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KINDS OF WATERWAYS

There are several kinds of grass waterways. Their design and type of vegetative cover depend on the purpose to be served and on the amount and velocity of water to be carried. We are concerned here only with those waterways on which a vegetative cover is necessary to make them most effective. They are:

1. Diversion terraces
2. Outlets
3. Natural waterways
4. Meadow strips

Diversion Terraces:

Diversion terraces are channels constructed across the slope on a small grade to intercept and divert excess surface water and minimize erosion or to prevent overflow of lower areas. Because of the slight gradient of these channels, water moves with low velocity. The erosive action of the water is small, and the demands made on the vegetative cover for protection are not great. A hay-type vegetation is used to give the necessary protection, provided it is properly mowed and fertilized. A hay crop can be harvested, and the diversion becomes a productive area. Rarely can diversions be managed economically as pasture.

Outlets:

Outlets are the type of waterways used to carry large concentrations of water usually from diversion terraces and often down steep slopes. The vegetative cover is often tested to and beyond its capacity on the steeper grades. It is important to have a tight sod-forming vegetation, well managed, and fertilized to withstand high velocities of water. The sole purpose of vegetation on outlets is to carry water and should be selected for this purpose rather than hay or pasture.

Natural Waterways:

Natural waterways are used to carry water where they can be fitted into the water disposal system. They are naturally developed drainageways leading into a woodland where trees and shrubs constitute the principal cover, or they result from concentrations of water flowing off cropland and should be left in grass.

Meadow Strips:

Meadow strips are used primarily in Virginia where the valleys are gently sloping and fairly wide. Such valleys can be managed in meadow crops and serve to spread and carry off water from the adjacent sloping land with a minimum of damage.

WATERWAY SITE SELECTION

Selection of a grass waterway site is one of the first considerations in planning a water disposal system. In general, the most satisfactory outlet for the disposal of water is a stabilized natural waterway such as a small stream or well-vegetated natural draw. These natural waterways can usually be spotted during field inspections of the area.

Occasionally, a natural waterway needs shaping or enlarging to handle the increased flow from terraces and diversions. In such cases, the design and construction should provide for a stable channel. When natural waterways are not present or practical, it is necessary to construct a channel for the removal of surplus water. Usually, constructed waterways are located parallel to field boundaries or property lines. It is important that the proposed location not only be adequate but also the best possible site available.

In selecting a site, the following questions must be correctly answered:

1. Will this location create an erosion problem to adjoining property, such as buildings, roads, culverts or other critical areas? If so, another site must be located.

2. Will the soil and moisture conditions be favorable to adaptable vegetative growth? If not, the site will not be a success. The waterway must be capable of establishing and maintaining a solid, water-resistant vegetative cover. Avoid a location bordering a shady woodland that would hinder vegetation.

3. Are the topographic and geologic features favorable for constructing a channel with enough depth and capacity for outletting terraces and diversions? They should be, if the waterway is to function properly.

4. Will crossing be at a minimum? The waterway should be located at the point of least traffic to minimize interference of entering the field or carrying out farming operations.

5. Do the site conditions favor the operation of construction equipment? The site should offer the flattest and most uniform channel grade in the area.

6. Is it possible to divert water away from the waterway until vegetation can be established? If not, it may not be possible to establish a vegetative cover without special treatment, such as mulch held in place by wire or fiber netting.

7. Will structures be required at the outlet end of the waterway to step the water down to a stabilized channel? If so, these structures must be planned in advance, at the time the waterway is being designed.

8. Will the waterway have to carry continuous flow from springs or seeps? If it does, the center of the channel must be properly protected by adapted vegetation or structures.

9. Will the site require drainage to establish stable channel conditions? If so, the drainage can be accomplished by proper tiling or stone center drains.

10. Are adequate roads and headlands provided to discourage the use of waterways as roads? Traffic on waterways is one of the major reasons for failures.

WATERWAY DESIGN

The design of a waterway is the determining of channel dimensions so that the estimated flow will be discharged without damage to the channel or the lining. The lining we are considering here is vegetation and soil. This lining can vary as to type and density.

The flow in waterways is generally considered to be "unsteady flow" when the discharge is changing at a cross section. The flow is also non-uniform since the mean velocity changes from cross section to cross section.

Flow in vegetated waterways is turbulent. Considerable energy is expended in this action. The eddying and "boiling" are visual forms of energy loss. These disturbances in the water are produced and maintained largely by roughness and irregularities of the bed. Sometimes they are produced and maintained by the severe whipping of the stems and leaves of the vegetation by the flow. The greater the disturbance, the greater the forces acting to scour the bed.

In vegetation-lined waterways there is a wide difference in velocities throughout a cross section. The water at the edges of the channel flows through the vegetation at low velocities. In the deepest part of the channel, where the vegetation has been bent over and submerged, resistance to flow is less and velocities are higher.

It is a common misconception that vegetation, bent over and completely submerged by flowing water, shingles the bed and forms a protective cover. Studies made by W. O. Ree at the Stillwater Oklahoma Outdoor Laboratory have revealed that the tested vegetation which included Bermuda grass, weeping love grass and yellow blue stem remains up in the flow. It waves and whips back and forth. The severity of this action is a function of velocity, vertical distribution (as affected by slope), depth of flow and roughness of channel flow. The least resistance is found where the flow is deepest. This is one reason small gullies sometimes develop in parabolic waterways.

Flow in grass waterways generally has a rough water surface. The more irregular the channel bed and vegetative growth and the higher the velocity, the

greater the surface roughness. A freeboard (the vertical distance between the designed water surface and the top of the berm) must be used to allow for displacement of water by entrapped air due to water surface roughness, the difference between estimated and actual discharge and capacity, and the displacement in the waterway caused by vegetation. Freeboards of .5 ft. are generally used. When adding freeboard to parabolic channel dimensions by increasing the depth we must increase the top width in proportion to the increased depth.

In selecting the design velocity for grass waterways consideration must be given to the (1) soil, (2) expected vegetation, (3) slope, (4) volume of flow, (5) climatic conditions, (6) structures, and (7) expected maintenance. Let us consider these 7 points.

Soil:

Soils can be classified according to their erodibility. This grouping usually refers to erosion-resisting and easily-eroded soils on bare land. In many instances the constructed channel is comparable to the condition of three erosion unless the top soil is stockpiled and spread over the exposed surface. The erosion-resisting soils usually are heavy soils, of clay or pans. In the heavy soils or through excavation, the soil may resist deep root penetration. Such soil is a factor in establishing and maintaining the expected cover which should be considered in selecting the design velocity. On the other hand, easily-eroded soils may permit deep and dense root penetration.

Good soil drainage is one of the most important prerequisites in the establishment and maintenance of vegetative cover in a waterway. Where soil in the channel is likely to be saturated a good part of the year the vegetation may be sparse in the center of the channel. Unless properly drained, the center section will be subject to severe heaving from frost action during freezing and thawing periods. The frost action will expose the surface. The result is usually a gully.

Two types of interceptor drains are most effective and practical for draining outlet channels. They are tile and stone center drains.

In tile draining an outlet a main is usually located outside of the channel, or a few feet to one side of the center line. It must be deep enough to accommodate short laterals installed at right angles to the main. The spacing of the laterals is determined by the site conditions but is usually closer spaced than tile in a regular field layout. It is a good practice to use a gravel filter on both main and laterals.

Stone drains are located in the center of the channel. A trench, usually a "V", is excavated about 2 feet deep (with minimum side slopes) below the designed waterway bottom. The trench is filled with stone, leaving the center 4" to 6" lower than the edges. The side slopes of the channel can now be finished to grade, ready for seedbed preparation.

Expected Vegetation:

From the evaluation of site and soil conditions we select the adaptable vegetal lining. With the above conditions as a basis, we have to determine the expected

cover as to its degree of retardance. The retardance factor is referred to as coefficient of roughness "n" used in Manning's formula which is used in determining the velocity.

The most important hydraulic characteristic of vegetation is the resistance it offers to flowing water. The resistance to or retardance of flow is approximately the same for a given vegetation regardless of type or slope of channel. The density and height of vegetation are the main factors that determine the resistance to flow. W. O. Ree, Hydraulic Engineer at Stillwater, Oklahoma, tested several grasses in the outdoor hydraulic laboratory in order to determine their retardance value under different types of management. As a result of these tests 5 classes of vegetal retardance were established and given letter designations. These are shown in Table 1.

Table 1

Classes of Vegetal Retardance and Physical Characteristics

Degree of Retardance	Stand	Length	Class
Very high	Good	30" +	A
High	"	11"-24"	B
Moderate	"	6"-10"	C
Low	"	2"-6"	D
Very low	"	Less than 2"	E

VR curves (velocity times the hydraulic radius) for each class of vegetal retardance given in Table 1 are shown in Figure 1. From these curves we can determine the retardance value "n" by projecting the product of permissible velocity "V" by "R" of a trial section to the curve for the expected vegetal class, then reading the "n" value on the left side of Figure 1.

Slope:

The slope is the channel slope which may be considered roughly the same as the water slope. We must carefully check changes in slope to determine if the permissible velocity "V" will be exceeded for a reach of increasing slope, or decreased on flatter slope, causing a lower velocity resulting in the overtopping of the waterway. Often the cross sectional area can be increased on the increasing slopes by widening the channel to obtain a reduced velocity. For abrupt slope changes it is often desirable to control the velocity by use of drop structures or chutes.

Volume of Flow:

The volume of flow is determined by standard procedures outlined in the Farm Planner's Engineering Handbook. It is important to establish time of expected peak flow in relation to the expected vegetal condition during that period. However, we must remember that time of peak flow may not be the period of worst hazard.

The expected flood flow may differ for each month of the year. The maximum flood flow and the highest retardance may not occur at the same time. The lowest retardance and the maximum flood also may not occur at the same time. Thus, in designing for capacity it may be unnecessary to use a combination of the extremes.

To determine the critical design period it is necessary to make a careful analysis of the seasonal variation in hydraulic characteristics and runoff for each locality or state. As an example, a 50-acre watershed has been selected for a given channel section and slope and the expected 10-year flood has been computed for each month of the year. See Figure 2. You will notice that the peak runoff of 150 c.f.s. occurs in May and nearly as high a discharge rate occurs in September.

The next step is to investigate the effect of the grass condition on the capacity of the channel. The maximum capacity of the channel for various cover conditions at different times of the year is shown on Figure 2. You will note that when the vegetation is allowed to be long, the channel will have its minimum capacity. If the vegetation is mowed or grazed to a length of 1-1/2 - 2", the channel will carry a greater flow rate. In this case the permissible velocity will be exceeded.

The second step is to study the permissible velocity in the channel. This is done by computing capacity of the channel without exceeding the permissible velocity. Figure 3 shows that it would take a discharge rate of 180 cfs before the water would be flowing at its permissible velocity. In this case, the channel would be overtopped since its capacity is 150 cfs at this stage of growth. If the grass is cut to a 4" length, the retardance will be less and the permissible velocity will be reached by a flow of 130 cfs. Since the flow rate may exceed this at two different times in a year, it is advisable to correlate the time of grass cutting with flood flow. If the grass is cut in mid-June, it will recover enough to slow the September runoff to a permissible velocity. Also, if the grass is kept grazed very short, the retardance will be so low that the permissible velocity will be reached with a flow of only 80 cfs.

We do not propose that this type of analysis be made for each channel. We recommend that a study be made of the runoff characteristics of the locality together with the seasonal characteristics of the vegetation to determine the critical design and vegetative management practice.

Climatic Conditions:

Climatic conditions are also considered in the design of grass waterways. Weather hazards, such as extremely high temperature, long periods of either drought or excessive rainfall, and freezing and thawing may reduce the density of the vegetal cover. In the northern states, the effect of snow and ice in the channel should be considered in the design.

Structures:

We should use structures for the stabilization of grass waterways where soil, slope and site conditions are such that vegetation will not provide the required protection.

Frequently, it is necessary to empty water into an existing channel where there is an abrupt drop of several feet to a stabilized grade. For overfalls up to 2 ft., it is possible to construct a sod flume by flattening the grade and sodding. We must remember, however, that the allowable velocity for the lining must not be exceeded in this section.

Drop structures, flumes, and detention dams are recommended for overfalls over 2 ft. to control erosion in stepping the water down to a lower elevation. For detail design, see Section 6 and 11 of the National Engineering Handbook.

Expected Maintenance:

The maintenance of the vegetation has a direct relationship to the retardance factor selected for the design. We should encourage farmers to manage the vegetal cover so that the growth and density of cover are kept within the limits of the retardance factor selected.

For the detail design of grass waterway refer to "The Farm Planner's Engineering Handbook."

SUITABLE GRASS SPECIES

Characteristics:

Grasses furnish protection to outlet channels by reducing the velocity near the bed. The best protection is furnished by grasses which produce a dense uniform cover near the soil surface. They must (1) be adapted to the locality and to the site conditions; (2) produce complete and uniform cover; (3) withstand bending and beating caused by flow; (4) withstand small amounts of sedimentation; (5) must be of such a growth type to provide maximum density and toughness at all seasons and following mowing or grazing; (6) must have deep vigorous root system primarily because a good root system is needed to support adequate top growth; (7) germinate, emerge and grow rapidly and (8) persist in adequate density for many years.

Species:

Tall fescue comes the closest to meeting the requirements under Northeast conditions. It is adapted to the climate in all of the Northeast, and is adapted to an extremely wide range of soil conditions. It germinates quickly and establishes easily. Although it spreads slowly, a dense cover will result if a uniform catch is obtained initially. Abundant basal leaf growth makes it almost impossible to remove the surface protection by mowing. The leaves are persistent through winter and tough enough to withstand abuse. It may be used alone or with redtop and birdsfoot trefoil. It may be used at 40-65 lb. rate when seeded alone. When seeded in mixtures use 40 lbs. fescue, 5 lbs. redtop and 10 lbs. birdsfoot trefoil per acre.

Red fescue has the ability to produce a very dense, uniform cover, has adaptation to climatic conditions at the higher elevations in Virginia, West Virginia and western Maryland, and for general use north of the Mason-Dixon Line. It is not as well adapted to wet soils as tall fescue and does not establish quickly or grow rapidly. Therefore, it should be used in mixtures

of about 30 lbs. red fescue, 5 lbs. redtop, and 10 lbs. birdsfoot trefoil per acre.

Kentucky blue grass has wide climatic adaptation but is adapted only to relatively good site conditions. It must have good fertilization and mowing in order to maintain adequate cover for long periods of time. Like red fescue, it does not establish quickly or grow rapidly and should be used with redtop. It should be used in mixtures of about 25 lbs. Kentucky bluegrass, 5 lbs. redtop and 10 lbs. birdsfoot trefoil per acre.

Reed canarygrass has a wide climatic range. It is best adapted to soils which remain wet much of the time. Its strong points are its ability to spread by rhizomes, thus filling in and healing scoured areas, and the terrific volume of growth which acts to cut down velocity. It is more exacting in seedbed, fertility and management requirements than the fescues or bluegrass. Its huge volume of growth can be a disadvantage on lower grades and in shallow channels. It does not provide a dense cover at the ground surface, particularly in early spring and immediately after it is mowed. It should be seeded with redtop and trefoil even though these species will not stay with it unless the waterway is mowed once about the time reed canarygrass heads out. The mixture used should be 20 lbs. reed canarygrass, 5 lbs. redtop and 10 lbs. birdsfoil per acre.

Creeping bentgrass (Agrostis palustris) will grow under very wet conditions. It is adapted to the cooler sections of the Northeast and may "burn out" on hot, dry sites. It establishes rapidly and is quick to make a dense uniform cover near the ground surface. It is shallow rooted and is subject to damage by diseases and hot, dry periods. The variety sold as "Seaside Creeping Bent" should be used. Use it in a mixture of 20 lbs. creeping bentgrass, 5 lbs. redtop and 10 lbs. birdsfoot trefoil per acre.

Bermuda grass and zoysia are being studied for their application in the southern part of the region. They offer promise for some conditions but need more trials to confirm their values.

ESTABLISHMENT OF COVER

The most practical and economical means of disposing of excess water on farms is usually through grass waterways. The establishment of good grass cover in waterways is attended by many problems, most of which are brought about by difficult site conditions combined with the erosion hazard during the establishment period.

Aside from general information gained from experience in seeding grasses on favorable sites, only a limited amount of information is available about seeding grasses in waterways. Numerous articles have been written about waterways. A review has been made of 83 of them. They contained very little information on waterway seeding that was based on research or systematic trials.

Experience and numerous field plantings by the Soil Conservation Service have furnished a background for local recommendations and have also served to point out the problems involved in getting grass established in waterways. The results obtained that relate to establishment are summarized as follows:

Liming, Fertilization and Seedbed Preparation:

Lime should be applied to bring the pH of the soil to 6.5 according to the needs as shown by a soil test. Best results have been obtained by applying manure at 15 tons per acre or more and 10-10-10 at 500 lbs. per acre. This fertilization is preferable to reduced quantities of manure with increased quantities of fertilizer substituted for it. Lime, manure and fertilizer should be worked into the seedbed thoroughly during seedbed preparation. Care must be taken to maintain channel shape, smoothness and capacity during seedbed preparation.

Timeliness of Seeding:

The early spring and August seedings were best. Mulching helped lengthen the seeding season. The use of a temporary erosion cover is recommended for planting in the off-season. The permanent seeding can then be made in a more favorable period.

Method of Seeding:

Any broadcast method that will distribute the seed uniformly and not cover it too deeply is satisfactory. Drill row establishment is objectionable unless it can be across the channel. The channel should be cultipacked or rolled after seeding to cover the seed and to leave the channel in a more erosion resistant condition. If a cultipacker or roller is not available use a wheel tractor back and forth across the channel until it is completely firmed.

Mulching:

Channels which are more than 300 ft. long and on slopes of more than 5% should be mulched, and the mulch tied in place. This is particularly necessary where water cannot be excluded from the channel during construction. Poultry netting, paper twine fabric, and criss-crossed twine have all been satisfactory when carefully applied. In most cases only the center 4' to 8' needs to be tied down. Mulching has been very beneficial in hastening establishment of the seeding. This is particularly useful on seedings made during June or September.

CONDITIONS UNDER WHICH SODDING AND SPRIGGING ARE APPLICABLE

Sodding is expensive. However, it is not needed under most conditions in the Northeast. It is used where a cover capable of carrying water is required in a short time. On very steep slopes sod is placed in bands or checkerboard arrangement to control erosion while a new seeding is being established.

Sprigging has a limited application and applies where seeding will not produce a good cover and where revegetation must be accomplished by means of vegetative propagation. Such plants as Bermuda, reed canary and quack grass may be established by sprigging.

MAINTENANCE

One of the first prerequisites of maintaining grass waterways is a recognition of the principle that the grass cannot carry greater velocities of water

than the rated capacities. Other precautions call for annual fertilization, mowing regularly for hay crops on diversion ditches and meadow strips, and at least two times during the season in outlets. Avoid using diversion ditches and outlets as roadways. To get the proper maintenance of waterways requires special training and appreciation on the part of the farmer. Whenever there is damage to a waterway it should be repaired immediately by sodding or shaping and reseeding.

Evidence is accumulating to show that mowing in outlets might be related to runoff to give best results. For example, peak runoff occurred between June 1 and August 1 in runoff studies conducted by Hobbs. See Figure 4. Under these conditions mowing about May 1-15 and August 15 to September 30 would favor greater protection by the vegetation. Always mow at least 4 inches high.

PERFORMANCE OF WATERWAYS IN VERMONT AND NEW JERSEY

A survey made recently in Vermont and New Jersey on the performance of outlets and diversions showed that they are holding up amazingly well in spite of a widespread lack of careful maintenance on the part of the farmer. Two soil conditions were found where the recommended vegetation, especially on outlets, had been a failure. This occurred on the light soils of southern New Jersey and the Champlain Valley clays of Vermont. The following is a summary of conditions found:

<u>Vermont</u>:

1. On the till soils and Grand Isle clay, vegetative control in outlets, diversions, and drainage ditches is working effectively. Some scouring was observed in channels where vegetation could not be established immediately. As might be expected, this was particularly true on higher grades. In all cases observed of older ditches, vegetation eventually became established and a good section maintained.

2. On the Champlain Valley clays, diversions, outlets and drainage ditches were eroding badly except on the lowest grades. Many ditches observed had cut into the channel from 1 to 6 feet. As a result of this cutting, the side slopes had fallen in and the width was constantly increasing. Despite this condition the farmers are generally pleased with the results obtained in removing excess water. Technicians and farmers have made great efforts to establish vegetation.

Trials have been made with different grasses including bluegrass, redtop, tall fescue, brome grass and reed canary. None was able to give satisfactory control except on gentle grades. It is possible that if vegetation could be established immediately by methods such as sodding, success might be obtained. On one farm, vegetation was successfully established on an outlet last year. Excellent treatment combined with fortunate weather conditions at the time of seeding contributed to the success.

3. Redtop was found to be particularly effective in channels. In some instances water had been flowing for several weeks over redtop, with no significant cutting action. Bluegrass was doing well on the berm and back slopes, but was not present in channels where water was present for any prolonged period.

4. There is a tendency for heavy stands of witch grass to develop on the berms.

5. Except in the Champlain clays, grass in the channel shows increased growth from fertility received from running water.

6. Stands of grass and legumes grew vigorously on the berms of all diversions. On the backslopes, a good erosion-resisting cover generally prevailed, but growth was stunted and not very productive.

<u>New Jersey</u>:

1. Diversions
   a. Generally well covered, with hay-type vegetation.
   b. Vegetation was managed and utilized as hay.
   c. Under hay-type management, there was little or no washing.
   d. Diversions had effective cover on berm, channel and backslope in the Coastal Plains, whereas subsoil exposures of channels and bank slopes on limestone and shale-type soils produced only sparse vegetation and some erosion.
   e. Considerable variation was noted in the width and management of filter strips above the diversions.
   f. Production of hay from the diversions could be increased by reseeding more frequently.

2. Outlets
   a. In general, except on the light sandy soils of south Jersey, the outlets reviewed showed varying degrees of cover where fertility and management were major problems.
      (1) Present fertilizer practices are not adequate.
      (2) Hay-type management does not produce desired sod.
      (3) Mowing too late where hay is not removed smothers vegetation.
      (4) Too often hay mixtures are being used for seeding.
      (5) While there was some erosion in many of the outlets it was the concensus of opinion that proper management, with recommended species, would effectively stabilize the areas.
   b. On the light sandy soils of south Jersey, bluegrass redtop mixtures have been ineffective in stabilizing waterway areas.
      (1) These soils are droughty, erodible and low in fertility.
      (2) Although this type of soil represents a relatively small acreage of the outlets reviewed, it occurs in the intensively cultivated vegetable areas where outlets are badly needed.
   c. There was considerable deviation from the use of recommended seed mixtures.
      (1) Seed is not readily available in all localities.
      (2) Farmers, for their own convenience, tend to use any mixture of seed on hand.
   d. While many of the outlets should be improved to give better protection, the farmers are generally satisfied with results obtained.
      (1) Farmers lack appreciation of the function and importance of the outlet to the conservation program.
      (2) Farmers do not recognize that improvement in management will materially increase protection.

As a result of these surveys the plant materials technicians have been working to secure species of plants that will be more effective on the Champlain clays and the light soils of southern New Jersey. While the results at present are tentative tall fescue and Bermuda are giving encouraging results. The survey also emphasized that farmers could get much better results from the vegetation used on waterways by observing more careful techniques in seeding and maintenance.

PERFORMANCE OF WATERWAYS IN NEW YORK AND PENNSYLVANIA

A recent survey which consisted of field checks of nearly all outlets and waterways in New York State revealed that a large number of them had suffered some damage. Spot rechecks in the field revealed that the damage was only slight in many cases, but the establishment of safe outlets still ranks as one of the major problems. Although such a detailed survey is not available for Pennsylvania, beginning in 1954 and continuing to the present time, many outlets in the state have been studied. Oral reports from each area in Pennsylvania, given at a recent statewide meeting of SCS personnel, stressed the need for means of safe water disposal as a major problem.

In both states outlets which are constructed to our design criteria, prepared and seeded according to service specifications are performing satisfactorily <u>if they can get through the critical establishment period undamaged</u>. It is assumed in making the above statement that if there are prolonged periods of seepage flow some means of drainage will be provided in the design and construction. Whether these outlets continue to function satisfactorily after establishment will depend upon the care and management which they receive.

One major problem is to develop practical means of protecting channels for a period of about two months following seeding. More attention should be given to means of excluding runoff from outside the channel area. We also need to determine the upper limits of slope and channel length (or accumulation area) on which vegetation can be established safely without protection. Most of the damage in outlets begins with the loss of a two to three inch depth in the channel center. This is usually the depth of material loosened in seedbed preparation. Each subsequent rain will cause additional damage to this unprotected area.

Current maintenance recommendations seem adequate. The problem is to convince the cooperator of the importance of the outlet so that he will give it the proper care and maintenance.

PIPE CREST GAGE MEASUREMENTS

To improve design criteria for grass waterways we need to obtain more information on the hydraulic characteristics of water flow in open channels. Research has developed certain criteria in outdoor laboratories but we need more information to adapt these data to actual field conditions in the Northeast.

It is very difficult, if not impossible, to determine the depth of flow after the water has receded. If the depth of flow at selected locations could be recorded, then the velocity for a channel reach could be computed.

The U.S.G.S. has developed a pipe crest gage for registering the maximum height of flow in open channels. We have made an adaptation of this design for use in the Northeast. The gage is quite easy to assemble from materials available at most hardware and plumbing supply houses. Drawing No. EP 372, sheets 1, 2 and 3 show details for assembling and installing the gage.

To measure the depth of flow in a channel we recommended that at least two gages be installed 50 feet apart in the center of the channel with gage point upstream. The bottom of the gage should be 1 inch above the channel bed. This distance plus the distance between the end of the tube and the cork cup is added to high water mark left by the cork. Readings are taken after each storm causing runoff. The cup is refilled with ground cork. When readings are taken, record the length and density of the vegetation.

PLANT MATERIALS - FIELD PLANTINGS

This report covers information gained from a total of one hundred and three field plantings which were established on outlets in eight northeastern states Thirteen of these are on constructed outlets in New York State. Sixty-five are on outlets and waterways in Pennsylvania. Eight of the plantings are minor plantings on short steep banks over which the water from single diversions is released. The remainder were in New England and on the coastal plain soils of New Jersey and Maryland.

Fifty-three of the above plantings were established during the spring and summer of 1955. Thirty-five were established during the spring and summer of 1956. The remaining fifteen were established in 1957. Two of the 1956 plantings were done over again in 1957 using tied-down mulch to protect the seedings. This method of protection was used in nine plantings.

<u>Species Used</u>:

Six permanent grass species have been tried. In mixture plantings, one permanent species and a temporary quick starting grass, either redtop or ryegrass, were used together. Birdsfoot trefoil was used with the two grasses in nearly all plantings. Plantings were also made using either tall fescue or Bermuda grass alone.

Redtop appeared much superior to ryegrass as a companion grass for the permanent species. Birdsfoot trefoil, where adapted, has made a tremendous contribution to the total cover during the summer months. It will also help to maintain the grasses.

The outstanding mixture based on rapidity of establishment, density of cover at all seasons (including immediately after mowing) and adaptation to the widest range of site conditions is: 40 lbs. tall fescue, 5 lbs. redtop, and 10 lbs. birdsfoot trefoil per acre. On the light sandy soils of the coastal plain, tall fescue seeded alone at 40 lbs. per acre has given excellent results when sown in late summer or very early spring.

A mixture of 20 lbs. reed canarygrass, 5 lbs. redtop, and 10 lbs. birdsfoot trefoil per acre was equally as good on the better sites where conditions were good for establishment. It lacks the range of site adaptation that tall

fescue has and requires more careful attention to seedbed preparation, seeding method and seeding date. Its use is also limited to steeper channels with ample depth.

At higher elevations in the southern part of the Northeast, or north of the Mason-Dixon Line, 20 lbs. creeping red fescue, 5 lbs redtop, and 10 lbs. birdsfoot per acre appears to be excellent once established. It is better adapted to the drier sites than tall fescue or reed canary and it will persist at very low fertility. More work is needed on the proportions of the different species in the mixture.

Creeping bentgrass has looked good in very wet sites. It shows potential for use in low gradient channels which stay wet for long periods.

Bermuda grass, as represented by the U-3 strain, has shown promise on light sandy soils in southern New Jersey. Sprigged in rows 18" apart across the waterway, it gave complete cover in 10 weeks and good protection soon after planting. Drawbacks are expense of planting and tendency to become a pest in adjacent cropland.

Another type of planting employed a 4-6" sod strip of U-3 Bermuda grass placed down the center of waterway, followed by overseeding of Ky-31 tall fescue. Purpose was to provide rapid-healing grass in area most apt to be scoured during seedling establishment period, with tall fescue providing remainder of cover. It was hoped tall fescue would restrict aggressiveness of Bermuda. Results are inconclusive to date.

Japanese lawngrass sodding has been very effective on one short steep bank below a diversion in southeastern Pennsylvania. It is probably not adapted north of this part of the state.

Reed canary sod has been effectively used on short, steep banks in northern Pennsylvania.

Seeding Date:

Early spring seedings and August seedings have been best. Mulching will help to extend the seeding dates some.

Work is needed on temporary crops to use when construction is not completed at a suitable date for permanent species. In New Jersey, spring oats were used to protect waterway constructed during early summer. The oat cover was disked into the soil in late August, the seedbed cultipacked, and tall fescue sown. The oats prevented erosion from summer storms and provided trashy residue when disked. An excellent stand of tall fescue then resulted. This principle can be applied summer or winter by using species adapted to the site and season.

Protection of the Seeding:

It appears that some method of protection is needed on seedings in channels which are more than 300 ft. long (or have an accumulation area over 1/4 acre which cannot be excluded) and on slopes of 5% or more. Mulch tied in place with paper twine fabric, or poultry netting, has been very satisfactory in

seven out of eight plantings. One successful planting involved the use of asphalt emulsion applied at the rate of .2 gal. per sq. yd. to tack down the mulch. This is twice the rate used on highway banks. Additional tests are needed to determine extent of protection under varied flows.

Summary

Observations of these plantings have emphasized the need for:

1. Careful site selection
2. Proper design and construction to that design
3. Adequate liming and heavy initial fertilization
4. Good seedbed preparation, including care in maintaining channel smoothness, shape and capacity
5. Timely seedings
6. Adapted species
7. Good seeding methods
8. Mulching the seeding particularly where some appreciable flow might occur and when seeding date is questionable

9. Good care and maintenance

RESEARCH UNDER WAY

Research under way in the Northeast is mainly on the problem area of the coastal plains of the Middle Atlantic States.

The objectives of this research are as follows:

1. To determine the most satisfactory seeding rates and combinations of grasses for quick erosion control with tall fescue in the general area of the coastal plains of the Middle Atlantic States.
2. To test grasses and planting combinations for waterways for quick erosion control with temporary grasses and ultimate erosion control with selected permanent grasses.
3. To determine the erosion resistance patterns for such grasses and combinations.

Additional exploratory research and field trials are under way with temporary tie-down material, such as plastics and open-mesh materials. Research is also being planned in New Hampshire which will have some bearing on this problem.

NEED FOR ADDITIONAL RESEARCH

The design and protection of waterways under favorable conditions of climate, soils and topography has been greatly facilitated by research already performed. The current needs for research information involve complex combinations of climate, soils and topography. These needs are:

Special Design Criteria:

Design criteria and types of vegetative protection for waterways in the northeastern states where slopes are steep, winter temperature extremely low and

prolonged, "trickle" flows are common. Glacial and sandy soils are among the soils on which this problem exists. The special gully problems of the Connecticut River Valley and Maryland tobacco area are also among those requiring research in this category.

Allowable Velocity Variations:

Determination of the allowable variations in velocity in a waterway. Significant changes in velocity create hydraulic disturbances which affect the capacity of the waterway and may be so severe as to damage the protective vegetative cover.

Maximum Safe Velocities:

Safe velocities for and the flow-retarding effect of adapted grasses and legumes now used but not previously tested in the Northeast in terrace outlets, grassed waterways, reservoir spillways and irrigation canals.

Establishing Vegetation:

Study of the relative value and economics of protective measures for initial establishment.

Gully Control in Waterways:

Economical means of controlling overfalls at the ends of waterways in areas where gullying is a problem. This has a high priority.

Retardance Factor for Grasses:

What is the retardance factor for different types and densities of cover under various degrees of growth, and different heights of cutting and different depths of flow?

Waterway Maintenance:

Methods of maintaining various waterway species under problem conditions. Time and height of mowing and fertility level are factors. Snow and ice removal are problems in northern states.

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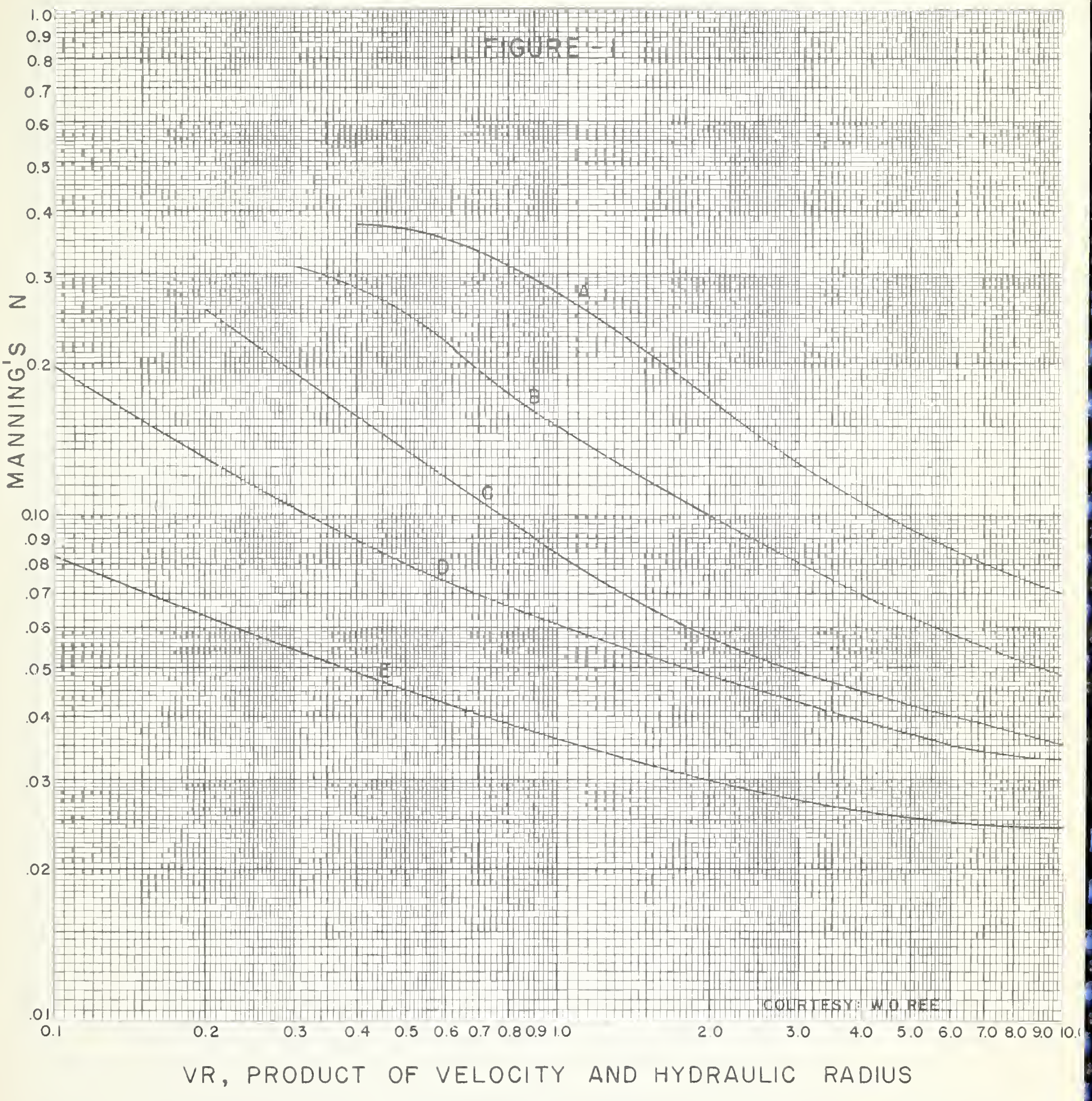
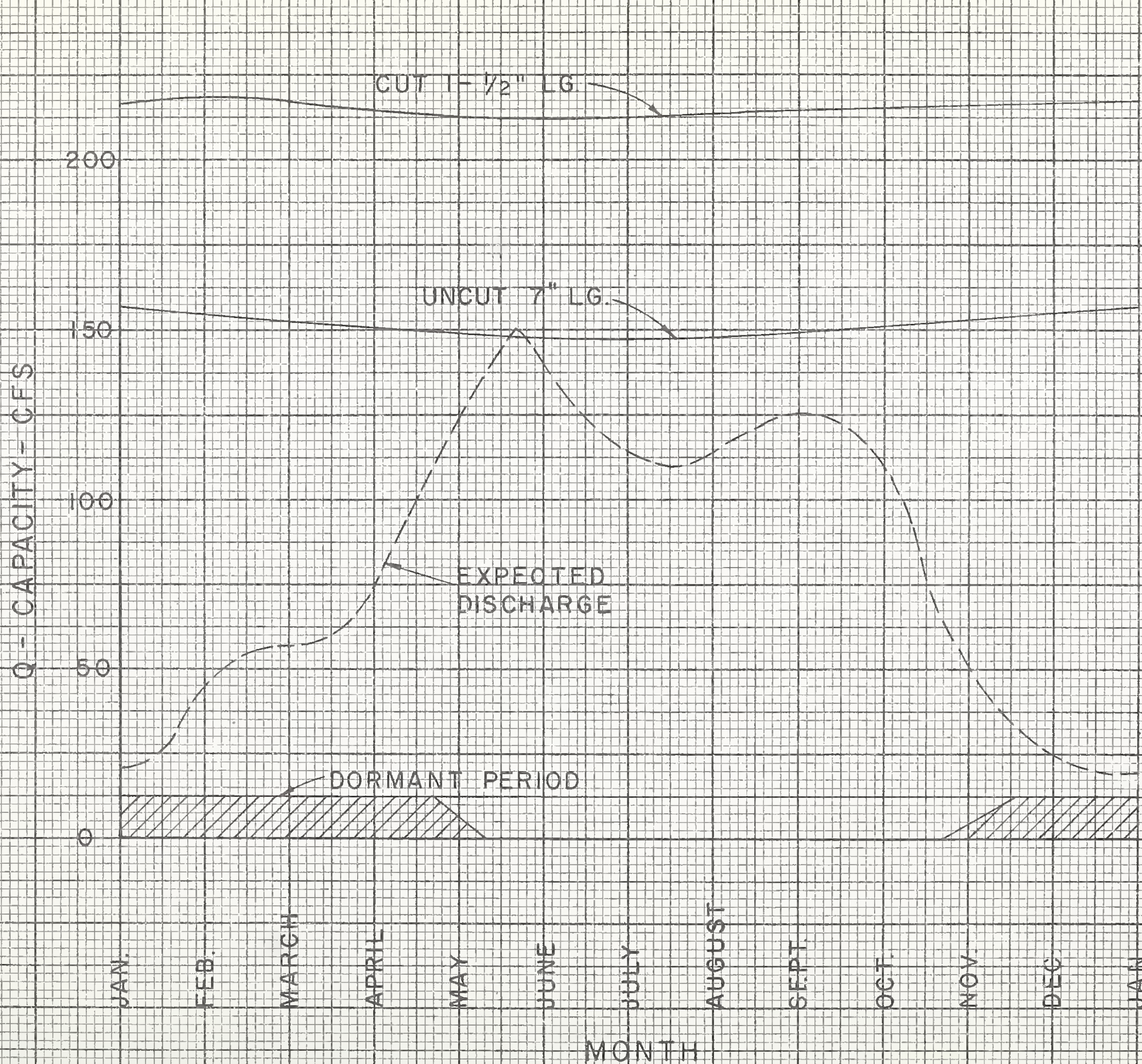


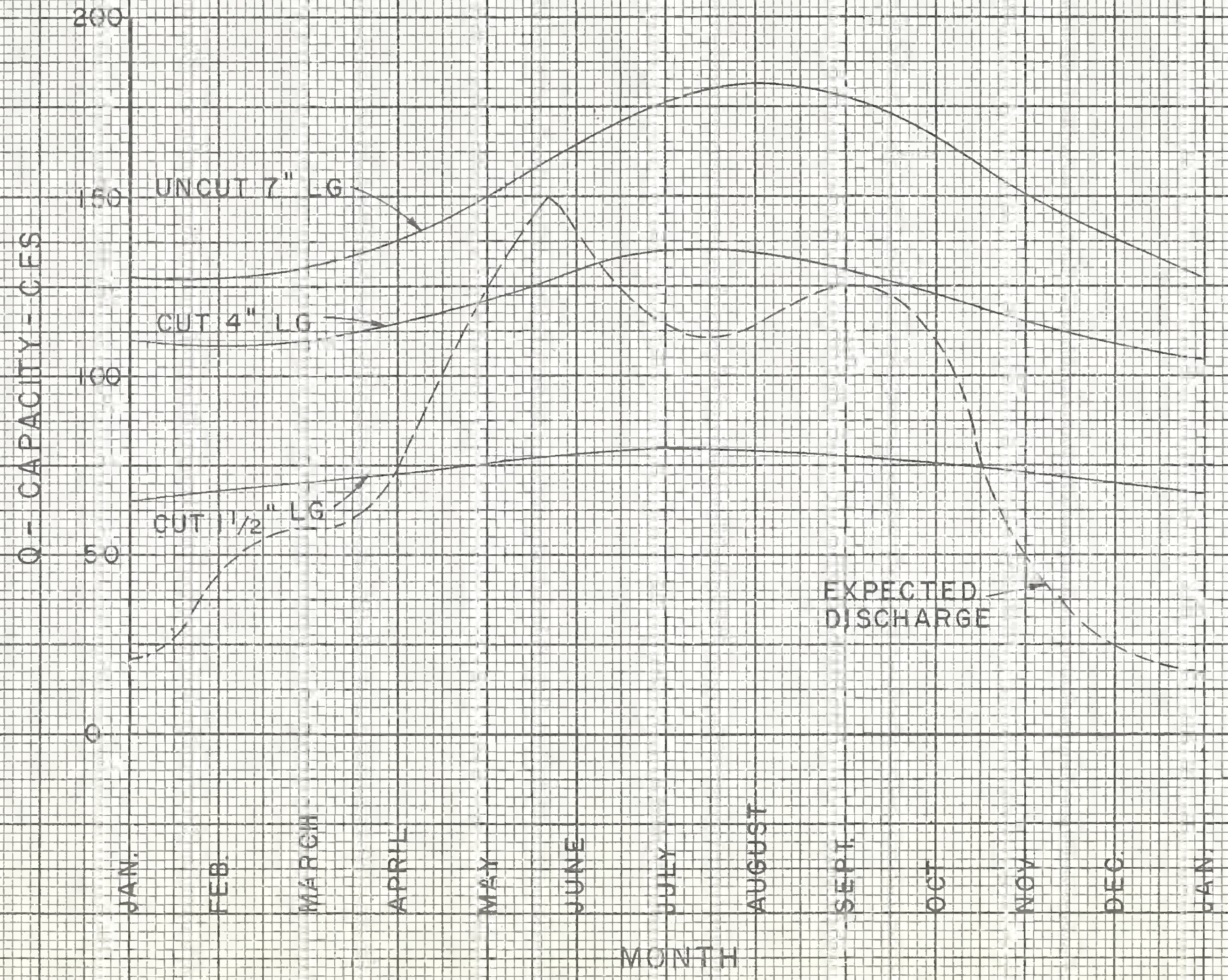
FIGURE-1
MANNING'S N
VR, PRODUCT OF VELOCITY AND HYDRAULIC RADIUS
A
B
C
D
E
COURTESY: W.O. REE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

FIGURE - 2



COURTESY: W.O. REE

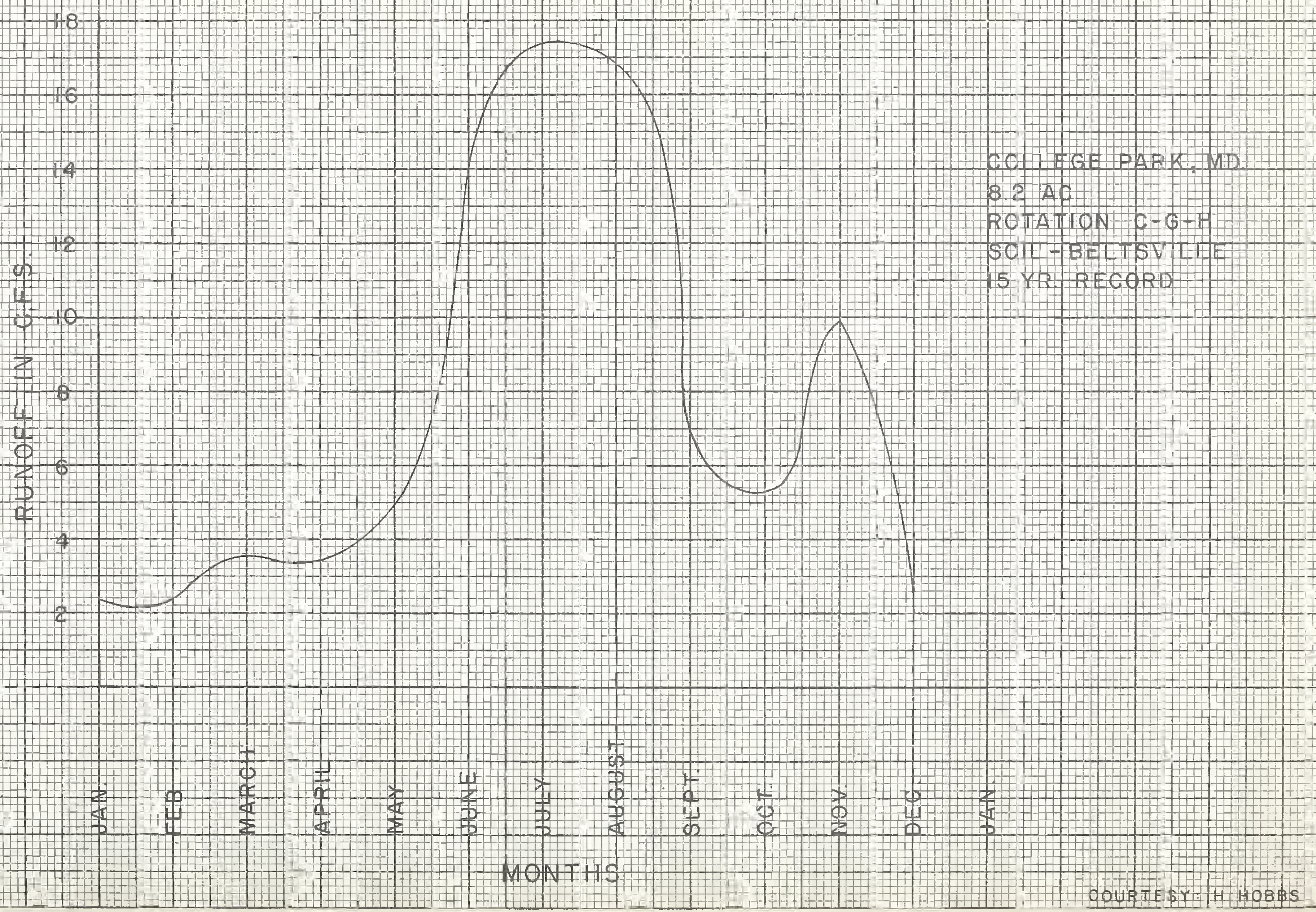
FIGURE - 3



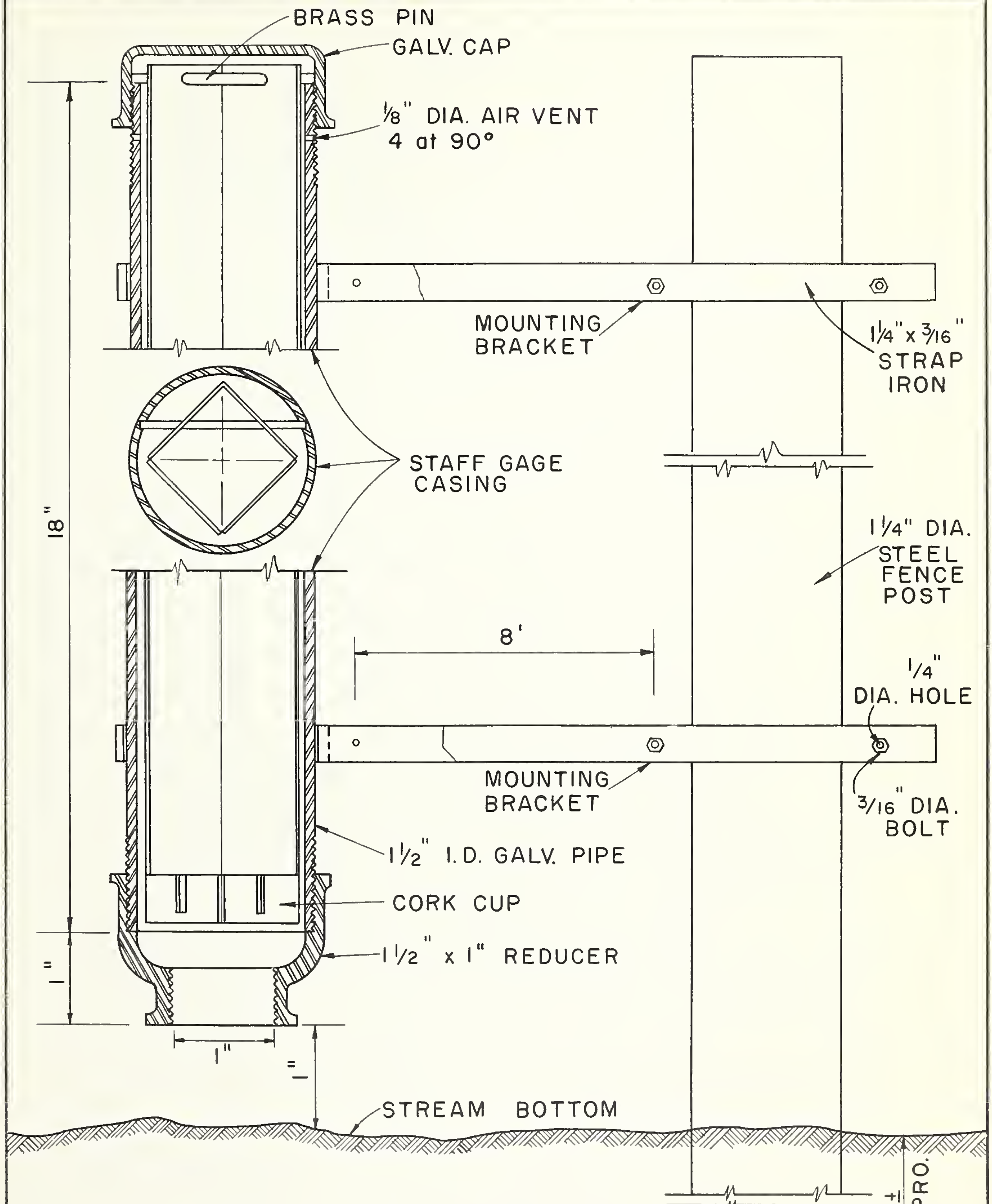
COURTESY: W. O. REE

FIGURE - 4

PEAK RUNOFF BY MONTHS FOR 10 YR. FREQUENCY



STAFF GAGE
(CORK CUP SUSPENSION ANGLE IN PLACE)



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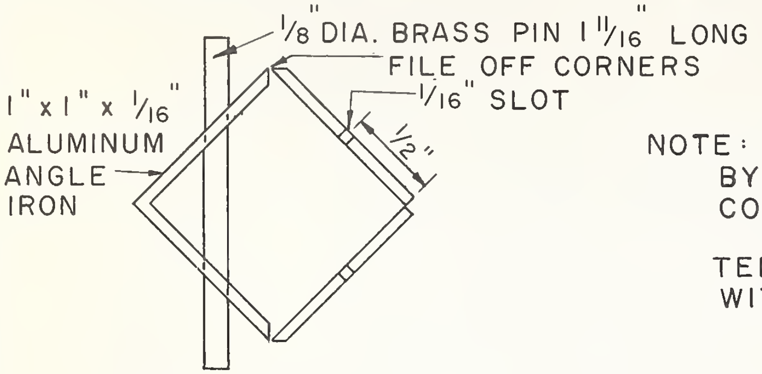
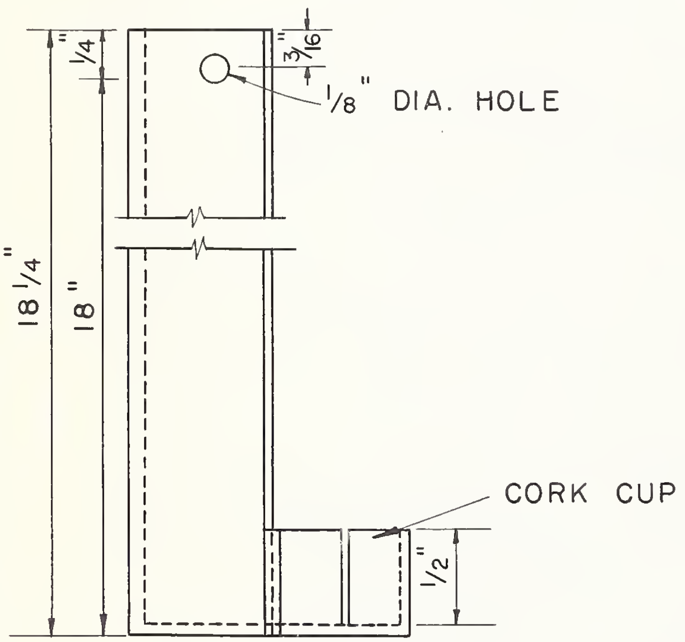
STAFF GAGE
DETAIL OF CORK CUP SUSPENSION ANGLE

TRUE SCALE

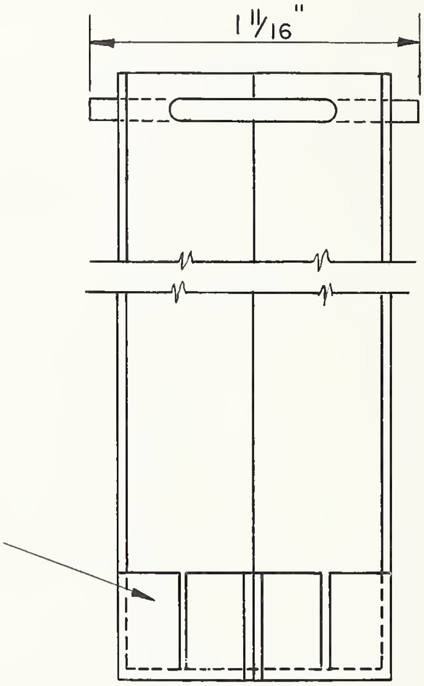


NOTE: USE CORK DUST PREPARED BY CUTTING CORK WITH A COARSE FILE OR FINE RASP.
MIX ABOUT 1% OF A DETERGENT SUCH AS DREFT, WITH CORK.

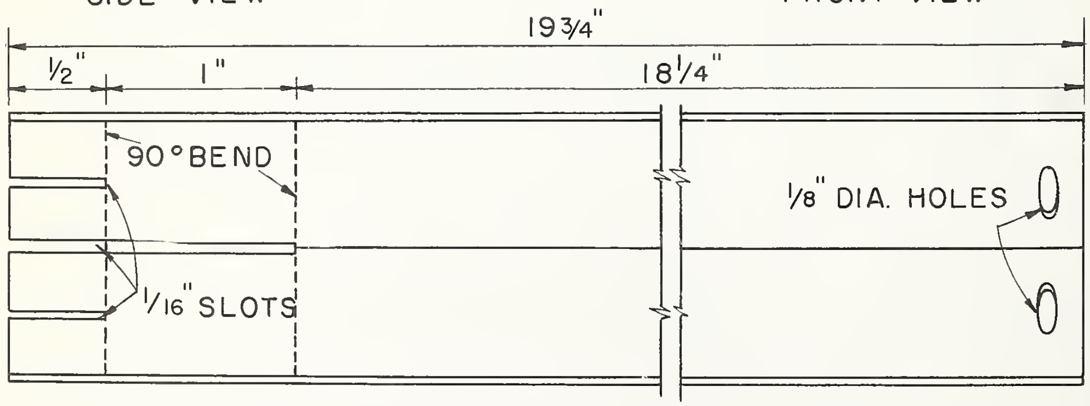
PLAN VIEW



SIDE VIEW



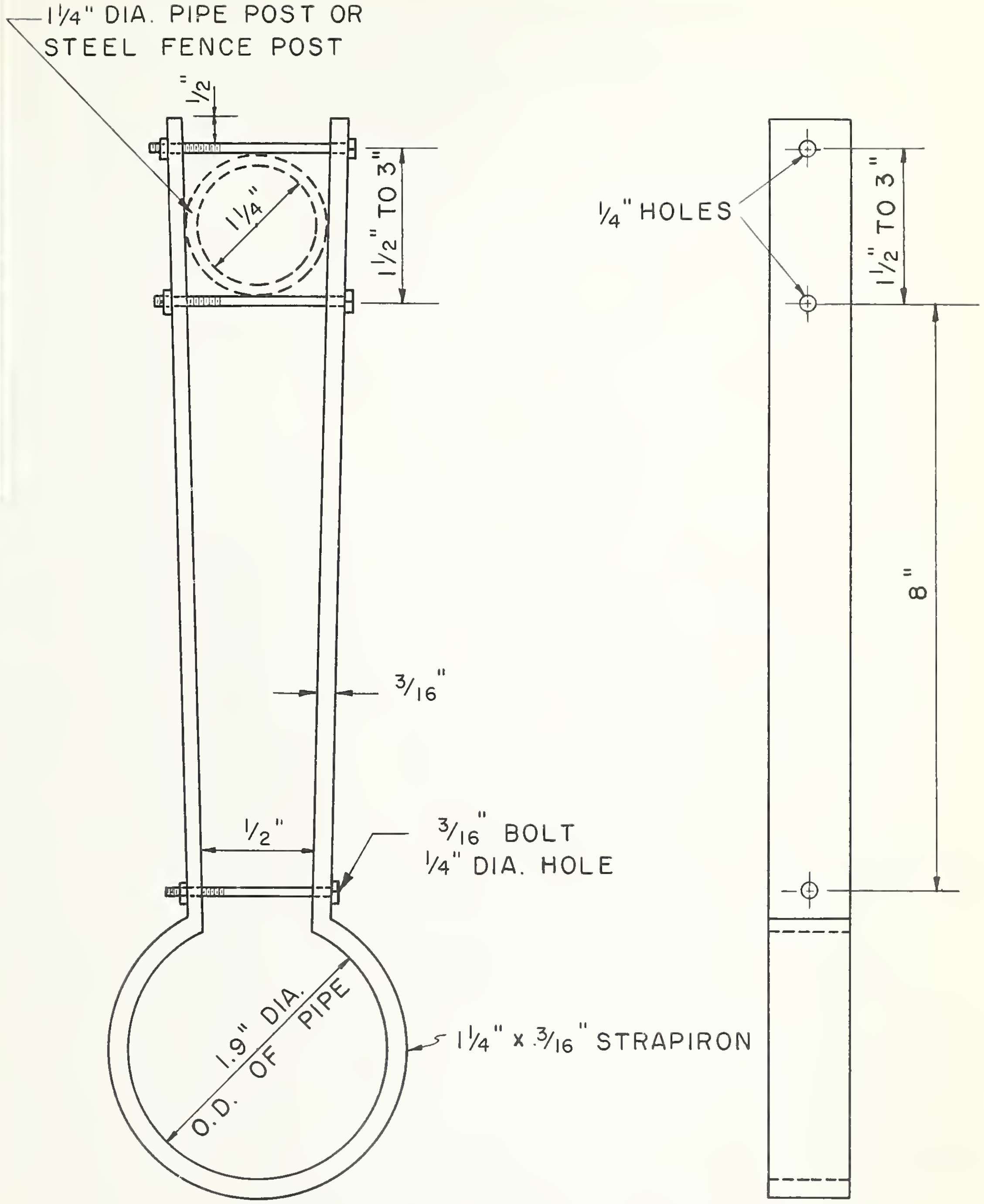
FRONT VIEW



DETAIL OF ALUMINUM ANGLE IRON

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	DRAWING NO. EP-372 SHEET 2 OF 3 DATE OCT. '57

MOUNTING BRACKET FOR STAFF GAGE



NOT TO SCALE

MATERIALS

STRAPIRON 1¼" x 28"
BOLTS 3/16" x 2"
" 3/16" x 2½"
POST OR STEEL FENCE 5'-1¼" DIA.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	DRAWING NO. EP-372 SHEET 3 OF 3 DATE OCT. '57